

AD-A089 740

SWEDLOW INC GARDEN GROVE CALIF
DETERMINE THE FEASIBILITY OF FABRICATING POLYPROPYLENE SPHERICA--ETC(U)
AUG 80 6 COOK
CT-FR-915-FR

F/G 17/9

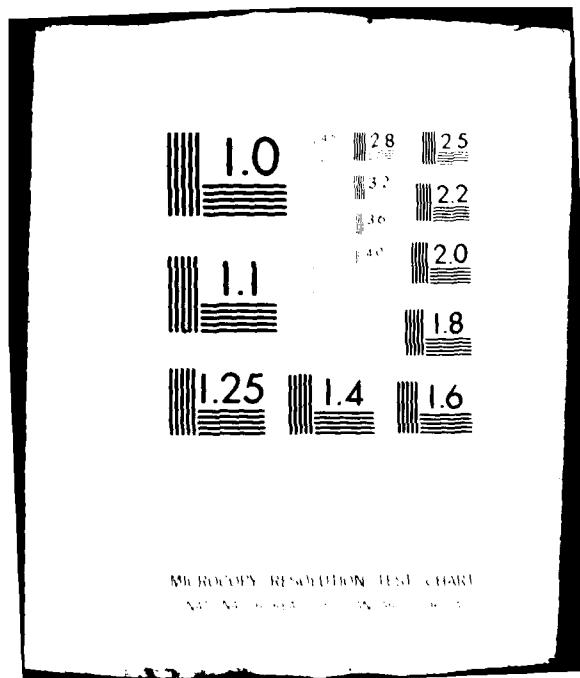
N00173-79-C-0266

NL

UNCLASSIFIED

1 of 1
455-A
100-200

END
100-200
FILED
11-80
DTIC



FINAL REPORT

LEVEL ~~II~~

SI ER-915

12 B.S.

DETERMINE THE FEASIBILITY OF FABRICATING
POLYPROPYLENE SPHERICAL ARMOR RADOMES FOR
PROTECTION FROM A LEVEL II FRAGMENTATION THREAT

AD A089740

FINAL REPORT

AUGUST 1980



NAVAL RESEARCH LABORATORY
WASHINGTON, D.C. 20375

PREPARED UNDER CONTRACT NO. N00173-79-C-0266

DOC FILE COPY

prepared by

S
SWEDLOW, INC.

This document has been approved
for public release and sale; its
distribution is unlimited.

12122 WESTERN AVENUE, GARDEN GROVE, CALIFORNIA 92645

80 9 26 050

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DETERMINE THE FEASIBILITY OF FABRICATING POLYPROPYLENE SPHERICAL ARMOR RADOMES FOR PROTECTION FROM A LEVEL II FRAGMENTATION THREAT.		5. TYPE OF REPORT & PERIOD COVERED Final Report, August, 1980
7. AUTHOR(S) G. Cook	6. PERFORMING ORG. REPORT NUMBER SI-ER - 915 - F	
9. PERFORMING ORGANIZATION NAME AND ADDRESS SWEDLOW, INC. 12122 Western Avenue Garden Grove, Ca. 92645		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 12 302
11. CONTROLLING OFFICE NAME AND ADDRESS NAVAL RESEARCH LABORATORY WASHINGTON, D.C. 20375		12. REPORT DATE August 30, 1980
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Armor Panel Polymeric Radar Antenna Hardening		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (See reverse side)		

~~UNCLASSIFIED~~

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DD 1473 Block No. 20

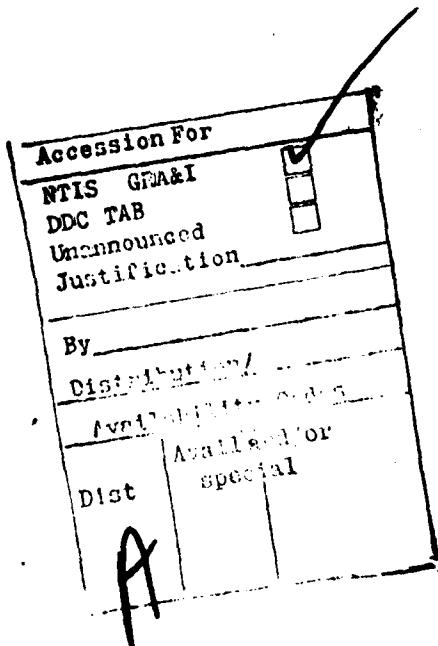
This program has as its objective the determination of the feasibility of fabricating polypropylene armor radomes. These radomes are required to provide protection for radar antennas from a Level II fragmentation threat. Four inch thick PP armor will be required to meet this threat level.

The plan was to develop processes based on the present state-of-the-art technology to fabricate four inch thick spherical radome sections, and to investigate edge-to-edge joining of flat polypropylene armor panels.

The thick spherical moldings are beyond the present technology and will require a new tooling and production approach. The present technology is limited to one inch thick flat panels.

The manufacture of several four inch thick radome shell sections with a 60 inch spherical radius established the feasibility of this approach. These panels were submitted to the Naval Research Laboratory for performance evaluation.

Adhesive and fusion bonded edge-to-edge joining methods were also developed. The systems evaluated indicate the feasibility of obtaining structural joints of PP armor panels.



SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SI ER-915

FINAL REPORT

DETERMINE THE FEASIBILITY OF FABRICATING
POLYPROPYLENE SPHERICAL ARMOR RADOMES FOR
PROTECTION FROM A LEVEL II FRAGMENTATION THREAT

FINAL REPORT

AUGUST 1980

NAVAL RESEARCH LABORATORY
WASHINGTON, D.C. 20375

PREPARED UNDER CONTRACT NO. N00173-79-C-0266

prepared by


SWEDLOW, INC.

12122 WESTERN AVENUE, GARDEN GROVE, CALIFORNIA 92645

SUMMARY

The primary objective of this project was to determine the feasibility of manufacturing thick (4 inch), curved plates composed of fusion bonded polypropylene films. This type of plate would ultimately find use as a radome material, providing ballistic fragmentation protection for ship-board radar antenna.

A secondary objective of the project was to determine methods of edge joining this type of plate to make larger structural elements.

Previous work conducted, which formed the basis for this project, dealt with the development of flat and relatively thin (1.0 inch) plates composed of the same materials. The general suitability of this material for radome applications was established in this prior work, but, the manufacturability and performance under altered conditions was unknown for the thick, curved plate configuration.

This project, conducted by Swedlow, Inc., was successful in demonstrating the feasibility of manufacturing thick, curved radome plates made from polypropylene films. Panels four inches thick having a 60 inch spherical radius were produced and submitted to the Naval Research Laboratory for performance evaluation. Preliminarily, these experimentally produced plates appear to be adequate for the intended application.

This project was also successful in identifying methods for joining panels. Both adhesive and fusion bonding techniques show promise, and offer potentials for further improvements, which should allow joint formation which will have structural value.

Also, this project resulted in the identification of methods which may be pursued for further improvements in the processes used for manufacturing such panels.

TABLE OF CONTENTS

<u>TITLE</u>	<u>PAGE</u>
INTRODUCTION	1
Statement of the Problem	1
Background	1
Objectives	2
Project Constraints	2
Statement of Work	2
PROJECT DESCRIPTION.	4
Schedule	4
Mold Design.	4
Lab Trials	4
Fixture Design	5
PROTOTYPE SPHERICAL SEGMENT MOLDING TRIALS	5
Molding No. 1.	5
Molding No. 2.	6
Molding No. 3.	6
Molding No. 4 & 5.	6
Processing Parameter Definition.	7
EDGE-TO-EDGE-JOINING INVESTIGATION	8
Adhesive Bonding	8
Fusion Bonding	9
CONCLUSIONS AND RECOMMENDATIONS.	9

TABLES AND FIGURES

PRELIMINARY ADHESIVE EVALUATION, TABLE I	11
BOND STRENGTH TEST RESULTS, TABLE II	12
FLOW DIAGRAM, FIGURE 2	13
MANUFACTURING OUTLINE, FIGURE 3	14
PROPEX DATA, DATA SHEET A.	18

TABLE OF CONTENTS (CONTINUED)

POLYPROPYLENE FILM PADS, DATA SHEET B.	19
FORM FIXTURE, DRAWING I.	20
SAW FIXTURE, DRAWING II.	21
SPHERICAL DIE ASSEMBLY DRAWING	22
SPHERICAL DIE ASSEMBLY DRAWING - REVISION B.	23

INTRODUCTION

Statement of the Problem

Shipboard radar antenna housings are presently fabricated of fiberglass reinforced honeycomb sandwich structures. These radomes offer little protection to the radar antenna from ballistic fragmentation threat.

The recent development of a new armor material comprised of fusion bonded plies of oriented polypropylene, may offer suitable ballistic protection while providing excellent radar transmission.

To determine the feasibility of fabricating polypropylene spherical armor radomes to provide improved survivability against Level II threats, certain state-of-the-art advancements are required.

At present the technology for the production of polypropylene armor is limited to the fusion bonding of one-inch thick flat panels. The transition from flat panels to thick spherical moldings brings with it several problem areas. Principally these are:

- o The increase in thickness required for Level II protection requires new fusion bonding processes. These processes will require lengthy heat up times and very accurate temperature controls to achieve the required molding temperature (340 to 355°F) throughout the desired 4.0 inch panel thickness.
- o Molding spherical panels will necessitate design and development of tooling concepts unique to the requirements of the fusion process.
- o Fabrication of molded curved segments into a large spherical structure will require the development of edge-to-edge joining techniques.

Background

Polypropylene armor is produced by taking plies of highly oriented polypropylene film, cross-plying to provide a uniform assembly, then fusion bonding the plies to provide a structural panel with excellent ballistic and radar transmission characteristics. The fusion bonding process requires containment of the oriented polypropylene film plies under high pressure (1000 to 2000 psi) while attaining a uniform temperature of 350°F throughout the panel. This allows a small portion of the plastic to melt and provide a bonding media without degrading the high degree of orientation of the film plies. Without this high pressure containment, the film plies will melt and lose all orientation at 323°F. The panel is then cooled under pressure to complete the fusion process.

Objectives

The objectives of this program were to determine the feasibility of fabricating polypropylene spherical armor radomes for protection from a Level II fragmentation threat. Armor thickness of four inches was selected to provide Level II protection (based on extrapolated ballistic data from AMMRC on 1 inch thick PP armor) while meeting the requirements dictated by the radar frequency selected by N.R.L.

Project Constraints

Due to limited funding, the program was established as a ten month effort to provide; a form die, four full sized molding trials, and a study of various bonding techniques to develop methods of joining segments into a radome structure. No funding was available for extensive mold development or additional molding trials to define processing technology.

Statement of Work

The stated objectives of the program were organized into the following tasks:

Task A: Produce four each 4-inch thick, 10 ft. diameter, 2 x 2 ft. polypropylene armor spherical radome shell sections. The production will employ the expertise and technology developed at Swedlow for the production of high quality polypropylene armor flat panels.

The effort will require new tooling and adaptation of the present technology. As such the work will be conducted on a "best effort" basis. The end product will rely heavily on existing flat panel technology.

Due to time and money constraints, only four of the spherical panels will be produced. The best trial parts will be submitted to the Navy for their testing for radar transmissibility and ballistic properties. The Navy will supply the polypropylene material required for the manufacture of the panels.

Task B: Swedlow will investigate edge-to-edge joining of the panels. This development work will be performed with flat panels only. Several edge configurations and surface conditions will be investigated under this task. This task will run parallel with production of the spherical panels.

Task C: The work and results of Tasks A and B will be documented and appraised. This will be incorporated in a final report which will document the findings, encountered problem areas, set forth potential solutions and alternatives and recommend, where necessary, new development work.

PROJECT DESCRIPTION

Schedule

A program organization outline was prepared (Figure 1) to provide a definition of the task requirements and provide scheduled completion dates for each task element.

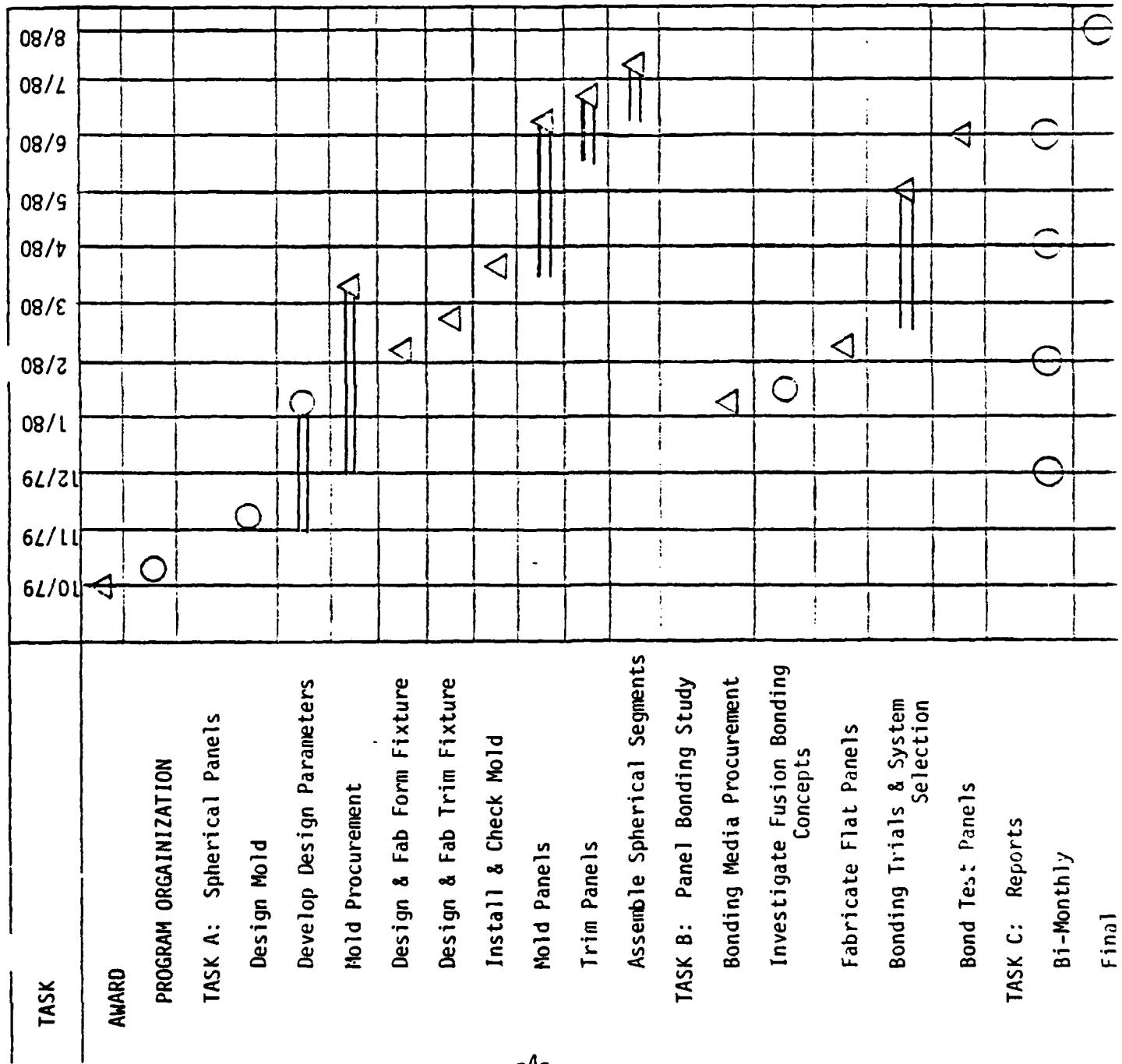
Mold Design

Based on the existing state-of-the-art technology, a steel compression mold was designed (Dwg. 79213) to mold 1.33 inch thick spherical segments. This thickness was chosen to minimize the risks associated with scaling up processes used on one inch thick flat panels. The design incorporated various inserts to permit the molding of segments with matching radii of curvature. Three separate moldings would then be bonded together to obtain a four inch thick panel with an outside radius of 60 inches and an inside radius of 56 inches. The bonding media would be selected to provide radar transmission characteristics matching those of the polypropylene armor panels. The mold design drawings were submitted to various mold and die shops for pricing. During this period, laboratory experiments were run in an attempt to develop processing parameters for the fabrication of PP panels at 2 inches and 4 inches thick. Each successful effort would simplify the mold design and reduce the overall program complexity. Prior to the successful fusion bonding of the 2 inch and 4 inch thick PP panels, mold prices were received which were above the limits established within the original program funding. The mold design was modified (Dwg. 79213 "Rev. B") to eliminate the various inserts which provided molded segments at matching radii. The final mold radii were established after completion of the 2 inch and 4 inch lab trials at 63 inch outside mold line (OML) and 59 inch inside mold line (IML). This ability to manufacture the final part in one operation should definitely enhance cost effectiveness of the final part.

Lab Trials

The basic processing parameters for producing armor panels from PP film provide severe constraints to scaling up to 4 inch thick laminates. The conventional process for molding 1 inch thick panels requires evacuation of the assembled film plies prior to and during the molding or fusion

FIGURE 1



process. The assembly is then pressed at 1000 to 2000 psi to a temperature of 345°F to 350°F to allow fusion of the film plies, followed by cooling under pressure to room temperature. Previous studies indicated that the oriented polypropylene film cannot be exposed to a temperature above 355°F without a severe reduction in ballistic efficiency, while reliable fusion bonding will not be obtained below 340°F. The problem then was to develop a molding process which would achieve a panel midpoint temperature of not less than 340°F while not exceeding a surface temperature of 355°F. Through a series of laboratory trials on 2 inch thick panels, various molding parameters were evaluated which provided a sound basis for a full 4 inch thick flat panel trial. The 4 inch thick flat panel trial successfully established the feasibility of molding full thickness spherical armor segments.

Fixture Design

A simple preform fixture (Drawing 1) to the IML was fabricated with glass cloth and high temperature epoxy resin. This fixture will be used to preheat and evacuate the PP material prior to the pressing operation. This was a round dome with a 4 inch flange large enough to permit layup of the 24 inch square film plies into a preformed spherical shape. The preformed assembly will remain on the fixture during the evacuation and drying cycle and be transported to the press.

A sawing fixture (Drawing 2) was also fabricated at this time with glass cloth epoxy construction. The basic design is a male form to the part IML mounted on a slotted masonite base. This served as a holding fixture during the band sawing operation with the slot engaging a guide bar mounted on the saw table. With the table tilted at 10.05 degrees, a 22 inch square segment can be accurately sawed from each molding.

The 22 inch segment sized was selected to provide the most efficient utilization of the available polypropylene film pads supplied by N.R.L. The scientific officer agreed to this small change in final panel size as being within the scope of the contract requirements.

PROTOTYPE SPHERICAL SEGMENT MOLDING TRIALS

Molding No. 1 (SN020780-1)

Some vacuum loss was noted during the production of the first spherical molding. During the introduction of the pre-heated, preformed film stack into the press, a sharp vacuum loss was noted. As pressing continued, vacuum loss was complete in fifteen minutes. An analysis of the processing procedure indicated that the PVA vacuum bag had become brittle from exposure to 250°F for sixteen hours. For one inch panels the preheat temperature is only 175°F, however the higher preheat temperature was necessary to achieve an acceptable midpoint temperature in a reasonable time with the four inch thick panel. As a result of the vacuum loss, the

molded panel had air bubbles or blisters just below the surface. The total area involved was about five percent of each surface, with the blisters ranging in size from about 1/2 inch in diameter to areas as large as one inch by five inches. The remainder of the panel appeared sound with no sign of delamination or unbonded sections. The maximum midpoint temperature was 334°F. The heat on cycle was 11 1/2 hours with the total cycle at 32 hours. The long cooldown period permits a gradual temperature reduction and minimizes thermal stress throughout the molded panel. Based on the laboratory experiments, removal of the molded panel from the press with a temperature differential within the panel of 40°F or more will result in internal delamination. A maximum temperature differential of 5°F was established for all 4 inch thick spherical moldings.

Molding No. 2 (SN021280-1)

The second panel was molded using a nylon film vacuum bag which eliminated the vacuum loss problem. This panel also had defects which appear as 1/8 inch wide surface ruptures running parallel to the film plies. Total involved area is estimated to be about one percent on each surface. The defects appeared to be caused by air entrapment on the surface. This could be corrected by the inclusion of woven oriented polypropylene fabric on the surface to act as a bleeder.

This fabric will also fuse during the molding cycle and provide a more durable surface to resist abrasion and UV degradation of the structure during outdoor exposure. (Data Sheet A).

Molding No. 3 (SN022780-1)

The third molding incorporated straw colored, UV stabilized, woven oriented polypropylene fabric plies on each surface during the fusion operation. The molded panel had an improved surface appearance with no evidence of air entrapment on either surface. There was some minor delamination noted below the surface in the central area of the inside spherical surface. This delamination appeared as a slight blister and involved about 10% of the panel area.

Moldings No. 4 & 5 (SN052980-1, SN060580-1)

The 4th and 5th moldings were made with polypropylene fabric plies incorporated on each surface. The moldings had excellent surface appearance and appeared to be structurally sound. During the sawing operation, the surface skins were observed to have separated from the laminate over most of the panel central area.

An analysis of the spherical panel during the molding operation indicates that with the mold radii matching at 4 inch panel thickness, there exists a constantly changing pressure pattern throughout the cycle.

During the fusion process, the film plies retain their integrity throughout the cycle; that is the layup structure is a series of thin flat plies which are stacked to form the spherical laminate.

During the compaction phase of the fusion process the pressure buildup will start at the four corners of the square layup, then proceed along each edge, then continue to the center. At exactly a 4 inch separation, the pressure will be uniform across the entire panel surface. Should closure continue below the 4 inch thickness, the pressure gradient will gradually reverse with the pressure buildup pattern following the opposite course. Under these conditions it appears that the orientation stress has been released in the surface plies of the 4th and 5th moldings due to lack of pressure in some areas. This stress is sufficient to overcome the poor interlaminar bond strength of the fusion bonded film plies and results in a delamination of the surface plies from the body of the armor panel.

It should be noted that all the spherical moldings made under this program had excellent structural integrity throughout. In each case the only problems with the final product were the minor surface defects noted.

It is apparent then that maintaining a positive pressure on the laminate throughout the fusion cycle is a critical requirement to reduce surface delamination. This requirement cannot be accomplished with the matched metal mold as presently designed. Alternate mold designs which are expected to over come this deficiency are proposed in the Conclusions and Recommendations Section of this report.

Processing Parameter Definition

The four inch spherical panels molded under this program represent a significant advancement of the state-of-the-art technology for fusion bonding of PP armors. These panels will be tested by NRL for radar transmission and ballistic efficiency. This will provide an excellent technical data base for future development of hardened tuned wall radar antennas. The processing parameters required for the fusion bonding of oriented polypropylene film into four inch thick spherical segments are shown in the flow chart (Figure 2) and the manufacturing outline (Figure 3). These procedures will apply to flat PP armor panels as well.

EDGE-TO-EDGE-JOINING INVESTIGATION

Adhesive Bonding

It was recognized at the onset of this investigation that it would be difficult to obtain an adhesive system which would provide a structural bond to polypropylene due to its non-polar and non-porous nature. As adhesive bonding systems have been developed to replace mechanical attachment in sophisticated aircraft and aerospace applications, this rapidly advancing technology must be considered for possible new developments to meet these requirements.

Various adhesive suppliers were contacted and their recommendations solicited. These suppliers all expressed concern over the ability to bond to polypropylene. Four candidate systems were selected for evaluation. The adhesives included epoxy, methylmethacrylate, and two urethane structural bonding systems. A preliminary bond test evaluation was established (Table I) to screen out promising candidate materials. Laminated PP armor panels were selected and the surface solvent washed with toluene to remove any oil or grease contamination, followed by an isopropyl alcohol wash to remove any traces of moisture. One half the bond surface was then treated with a propane flame to activate bond sites. This is an accepted method of promoting adhesion to polypropylene film. The adhesive systems were mixed according to the manufacturer's instructions and applied to each prepared surface.

A peel test was used to screen the bond integrity. After full cure, each bond was subjected to peel forces by inserting a blade under a corner of the bond joint. Bond strength comparisons were based on the resistance to peel and the condition of the polypropylene surface after removal of the bonding media. Any evidence of polypropylene being removed with the bonding agent would indicate a bond tensile strength approaching that of the tensile strength of polypropylene. The peel strength ratings were "fair" for the two urethanes, "poor" for the epoxy, and "no bond" for the acrylate systems. Examination of the bond area after adhesive removal indicated a slight mechanical bond for the urethanes.

Bond tensile strength studies were run on the three best systems. The anaerobic adhesive (Loctite 324) was supplied with a primer designed to promote adhesion to polypropylene. The other two were tested as supplied and in conjunction with a primer developed by Reliance Universal, Inc. to improve paint adhesion to polypropylene. The test data shown on Table II indicate bond tensile values of 500 psi can be obtained on edge bonded PP armor panels. The primer, PolyPrime #91 was also tested at NRL as an undercoat for standard deck paint on PP armor panels, and found to provide excellent adhesion.

Fusion Bonding

Fusion bonding of the polypropylene using ultrasonic welding was investigated. Ultrasonic plastic assembly of thermoplastics is a standard production process used for thousands of products. Present state-of-the-art technology is limited to 1/4 inch thick bonds for most applications. Trials with 1 inch thick PP laminates resulted in poor replication of bond line fusion. With the low bond tensile strength properties of the PP laminate, the high frequency vibration energy concentrated at random sites throughout the laminate causing melting and fusion to occur at areas other than the selected joint line. Technical evaluation of the problem by the ultrasonic system's engineers indicated the large bond area and high mass involved in joining large thick PP panels cannot be accomplished by ultrasonic bonding due to the limited area which can be treated by conventional equipment. Vibration welding at 120 HZ (Vs 20K HZ for Ultrasonic Welding) has been developed for large area fusion bonding. Equipment design utilizing this technique would be based on final PP armor panel size and shape and the required bond line area. They feel this would be a viable concept for edge joining PP armor panels.

One inch thick panels were joined along a 12 inch bond line using a heated platen to melt the polypropylene along the desired joint line. The parts were then clamped together and allowed to cool. These panels were submitted to NRL for evaluation. Lab specimens prepared on 1 inch by 2 inch PP laminates were tested for ultimate bond strength. The average value was over 500 psi (Table II) with cohesive failure evident in all cases. Close examination of the failure mode revealed a wide variance in percent bond area. The average bond area appeared to be approximately 40% fused. This indicates the bond strength of 100% fused joints can be expected to approach 1000 psi. NRL test results on the Swedlow test panels were considerably lower, with projected ultimate bond tensile values of 300 psi. It is apparent that the larger bond area of the NRL panels (12 square inches vs 1 square inch) resulted in a more shallow melt area and a subsequent reduction in ultimate bond strength. Based on the tensile strength of unoriented polypropylene homopolymer, the theoretical fusion bonded joint tensile values should approach 3000 psi. This value should be attainable with edge bonded PP armor panels with proper tool design and process refinement.

CONCLUSIONS AND RECOMMENDATIONS

The program objectives were realized through this effort. Processing technology for the fabrication of four inch thick spherical radome sections has been developed. Edge joining techniques to provide structural bonding of PP armor spherical segments have been developed.

Successful fusion bonding of four inch thick spherical PP armor panels represents a significant advancement of the state-of-the-art technology. As a result of this advancement, Swedlow, Inc. has received a new contract from NRL to mold 25 3.6 inch thick PP armor panels. These panels will be joined to create a geodesic radome structure to be tested for combat survivability. A comprehensive analysis of the electrical and structural performance under all environments will be made. The production of PP armor panels will verify the processing technology developed under this program and provide a solid data base for the development of process improvements.

Recommended additional development effort should address the following problem areas:

1. Develop mold design concepts to provide uniform pressure on the laminate throughout the entire molding cycle. Modify present spherical die assembly to conduct laboratory experiments.
 - o Silicone rubber pad on matched metal mold to provide uniform pressure distribution.
 - o Male pressure bag containing heat transfer media for more uniform pressure distribution as well as more efficient heating/cooling phases.
 - o Develop mold designs for full scale production capability from the above studies.
2. Expand edge joining technique studies to provide structural bonding of 3.6 inch thick spherical segments.
 - o Design laboratory scale equipment to achieve fusion bonded joints which approach 3000 psi tensile strength (This is the tensile strength of polypropylene homopolymer).
 - o Continue evaluation of candidate adhesive systems for structural edge joints.
 - o Develop designs and determine power requirements for full scale production capability of sonic bonding equipment.

TABLE I
PRELIMINARY ADHESIVE EVALUATION

<u>Adhesive System</u>	<u>Type</u>	<u>Peel Strength</u>		
		<u>Solvent Washed A</u>	<u>Heat Activated B</u>	<u>Surface Treatment</u>
Houghson 521	Acrylic	No Bond	No Bond	No Bond
3 M 3549	Urethane	Fair Bond	C	Poor Bond
3M 2216 B/A	Epoxy	Poor Bond	Poor Bond	Poor Bond
Tycel B 2801	Urethane	Fair Bond	C	Poor Bond
Loctite 324	Methacrylic Ester	Fair Bond	C	Fair Bond

- A. Solvent washed with Toluene followed by Isopropyl Alcohol scrub.
- B. Apply blue cone of propane torch flame to bond area to activate bond sites.
- C. Examination of bond area after peeling, indicates some trace of cohesive failure. Candidate systems to be evaluated for bond tensile strength of edge-to-edge joints.

TABLE II
BOND STRENGTH TEST RESULTS

<u>Adhesive System</u>	<u>Bond Strength Average PSI</u>	<u>Comments</u>
3M 3549 (1)	165	Adhesive Failure
3M 3549/Poly-Prime #91 (2)	433	Adhesive Failure - Surface primed with Poly-Prime #91.
Tycel B2801 (3)	274	Adhesive Failure
Tycel B2801/Poly-Prime #91	547	Adhesive Failure - Surface primed with Poly-Prime #91.
Loctite 324 (4)	269	Adhesive Failure
Fusion Bond (5)	545	Cohesive Failure - Bond area varied from 5% to 80%. Average area bonded 40%.

Source

- (1) 3M Company, St. Paul, Minn. 55101
- (2) Reliance Universal Inc., Somerset, N. J.
- (3) Lord Corp. (Hughson Chemicals) Erie, Pa. 16512
- (4) Loctite Corp., Newington, Ct. 06111
- (5) Panels bonded by placing specimens against 450°F hot plate for 60° seconds, then joining under hand pressure until cool.

FIGURE 2

FLOW DIAGRAM - 4 INCH THICK SPHERICAL PP ARMOR PRODUCTION

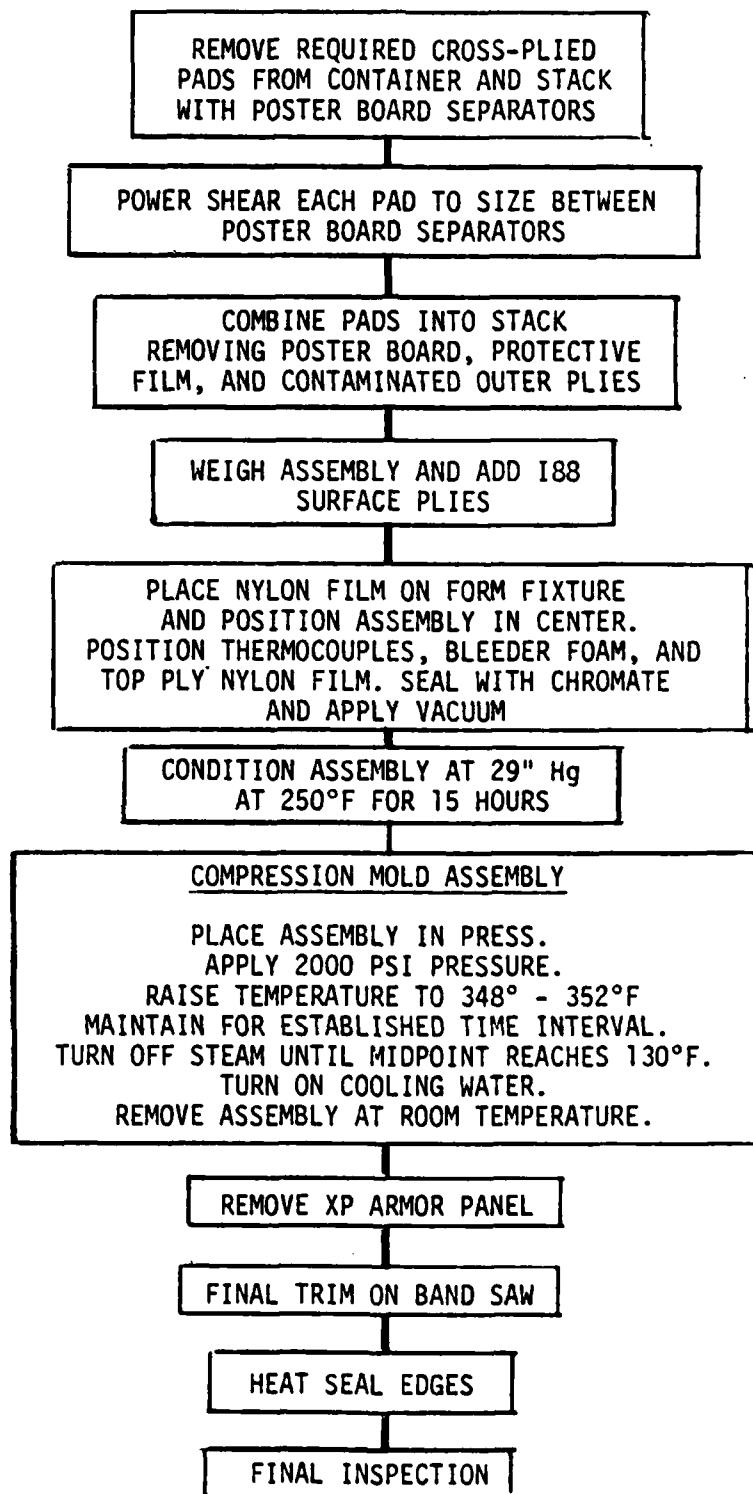


FIGURE 3

MANUFACTURING OUTLINE

PP ARMOR PRODUCTION - 4" SPHERICAL SEGMENTS

STEP 1 MATERIAL CHARGE WEIGHT CALCULATION

Determine desired sheet size and thickness.

Calculate charge weight based on theoretical Sp. Gr. of Polypropylene (.91 gm/cc) plus 3% flow factor.

Example:

To mold a 4.0 inch thick spherical segment with final dimensions 22 inches square, cut PP film pads (Data Sheet B) to 23.5 inches square to allow 3/4 inch trim.

Calculation:

$$\begin{aligned} 23.5" \times 23.5" \times 4.0" & \text{ (Desired panel thickness)} \times 16.4 \text{ cc/in}^3 \\ \times .91 \text{ gm/cc} & \text{ (Sp. Gr. of Polypropylene)} \times 1.03 \text{ (for 3% flow)} \\ = 33,956 \text{ gms.} & \text{ Include weight of surface plies in final assembly.} \end{aligned}$$

Determine number of cross plied oriented polypropylene pads required for each panel. Example calculation with the AMMRC supplied material at 1.25#/ft². (567 gm/ft²)

Calculation:

$$\frac{\text{Desired wt of XP mat'1. (gms)}}{\text{Area of panel (ft}^2\text{)}} \times \frac{1}{567 \text{ gm}} \text{ ft}^2 = \text{No. of pads}$$

$$\frac{33,956}{23.5 \times 23.5} \times \frac{1}{567} = 15.6 \text{ pads} \therefore \text{use 16 pads}$$

STEP 2 MATERIAL PREPARATION

Put on thin white cotton gloves for the following operations. Place each PP pad on a piece of .050 inch thick white poster board. Place a sheet of poster board on top and trim the layup to size on the power shear. Position all the layups on one stack and then re-stack while removing the polyethylene film and the separator boards. This is done as follows:

- A. Remove top board and position next to layup stack.

FIGURE 3
(Continued)

Remove polyethylene film and any layers of oriented polypropylene which exhibit contamination.

Replace top board and grasping edges of top and bottom board from one pad, flip over and position beside layup stack.

Remove the present top board.

Remove the polyethylene film and any layers of oriented polypropylene which exhibit contamination.

Replace the top board.

B. Repeat the above sequence with the second pad.

Place on top of the first pad.

C. Carefully remove the two middle cardboard plies by uniformly pulling them out in opposing directions at the same time.

D. Repeat steps B and C with each pad until the entire layup stack is complete.

STEP 3 WEIGHING LAYUP

Wear white cotton gloves.

Place a clean carrier plate and top ply of poster board on a scale and tare to zero.

Place two ply I88 fabric (cut 1/4" oversized and washed with methanol) over the assembly, replace the posterboard, then carefully invert the entire assembly onto the scale.

Remove the poster board and carefully skin back layers of the oriented polypropylene until desired weight is obtained. (Desired weight equals calculated weight less the weight of two ply of I88).

Position two ply of cleaned I88 on top of the assembly.

STEP 4 EVACUATING ASSEMBLY

Place the carrier plate next to the preform fixture. Lay a sheet of nylon bag material on the fixture, then slide the assembly onto the preform fixture.

FIGURE 3

(Continued)

Place high temperature bleeder foam around the assembly and position thermocouple 3/4" in at midpoint location.

Form a vacuum bag around the assembly using high temperature zinc chromate.

Pull vacuum to 29 in. Hg. Draw down the assembly during evacuation to form spherical segment.

Place assembly in an oven at 250°F for 16 hours.

STEP 5 MOLDING

Turn off vacuum pump and transport assembly to the press. Be sure vacuum valve is closed to maintain vacuum on the assembly.

Turn on vacuum pump and steam and close press to 2000 psi on the laminate.

Pack 4" of fiberglass insulation around assembly.

Connect thermocouple leads to potenteometer.

Record all data on Molding Record every 15 minutes.

Maintain platen temperatures at 348°F to 352°F during heat on cycle.

For a four inch nominal panel maintain steam on until midpoint temperature reaches 335°F (Minimum).

Turn off steam and open bypass.

Record data on Molding Record every hour.

Turn on cooling water at 130°F midpoint temperature.

Remove panel at room temperature with maximum allowable temperature differential of 5°F from panel surface to midpoint.

STEP 6 MACHINING PANEL

Band sawing can be accomplished with a 1 1/4" Starret Premium Hook Tooth Blade with 3 teeth per inch. Keep blade tension very high and feed work slowly with saw speed at 70 to 80% of maximum.

Tilt saw table to 10.05°. Attach 3/4" square guide bar to saw table. Clamp molding to saw fixture and position over guide bar. For hand feeding, apply a paste wax to the saw table and the underside of the fixture to promote a smooth feed rate.

FIGURE 3
(Continued)

If sawed edge is of sufficient quality for the intended application, heat sealing will not be required. This is due to the heat build up during the sawing operation which fuses the PP film plies.

For a more accurate machined edge, the sawed panel may be routed as follows:

Clamp on milling machine table with 1/8" thick acrylic (or other non-metallic rigid material) on top and bottom along trim edge.

Route edge with 1/2" diameter - 2 flute carbide router at 18,000 RPM to final dimensions.

ALTERNATE MACHINING METHOD

Clamp untrimmed panels on milling machine table with 1/8" thick acrylic (or other non-metallic rigid material) on top and bottom along trim edge.

Cut edge with a carbide inlay saw blade with 1/4" wide teeth on a 30 inch diameter blade at two teeth per inch.

Blade speed - 238 RPM
Feed speed - 1.42 inch/min.
Coolant - Water soluble TL 131

STEP 7 HEAT SEALING EDGES

Clamp trimmed edges with metal bars to prevent relaxation of the oriented film during the fusion operation.

Hold a butane torch flame approximately one inch from the edge of the panel, and move the flame back and forth until the entire edge exhibits a high gloss due to localized melting of the polypropylene. Allow to cool to room temperature before releasing the clamp pressure.

DATA SHEET A

PROPEX^(R) DATA SHEET

I-88

TYPICAL PROPERTIES

MATERIAL	POLYPROPYLENE	
COLOR	GOLD	
TENSILE STRENGTH, LBS.	ASTM D-1682	400 X 400
BURST STRENGTH, PSI	ASTM D-751	> 750
TRAPEZOID TEAR STRENGTH, LBS.	ASTM D-2263	> 125 X 125
UV RESISTANCE STRENGTH RETENTION, %	FEDERAL TEST METHOD CCC-T-191 METHOD 5804 AFTER 1200 HRS. OF EXPOSURE	> 70
WEIGHT, OZ/YD ²	ASTM D-1910	8.5

AMOCO FABRICS COMPANY
Patchogue Plymouth Division
Suite 150
550 Interstate North
Atlanta, Georgia 30339

DATA SHEET B

UNIAXIALLY ORIENTED POLYPROPYLENE FILM PADS

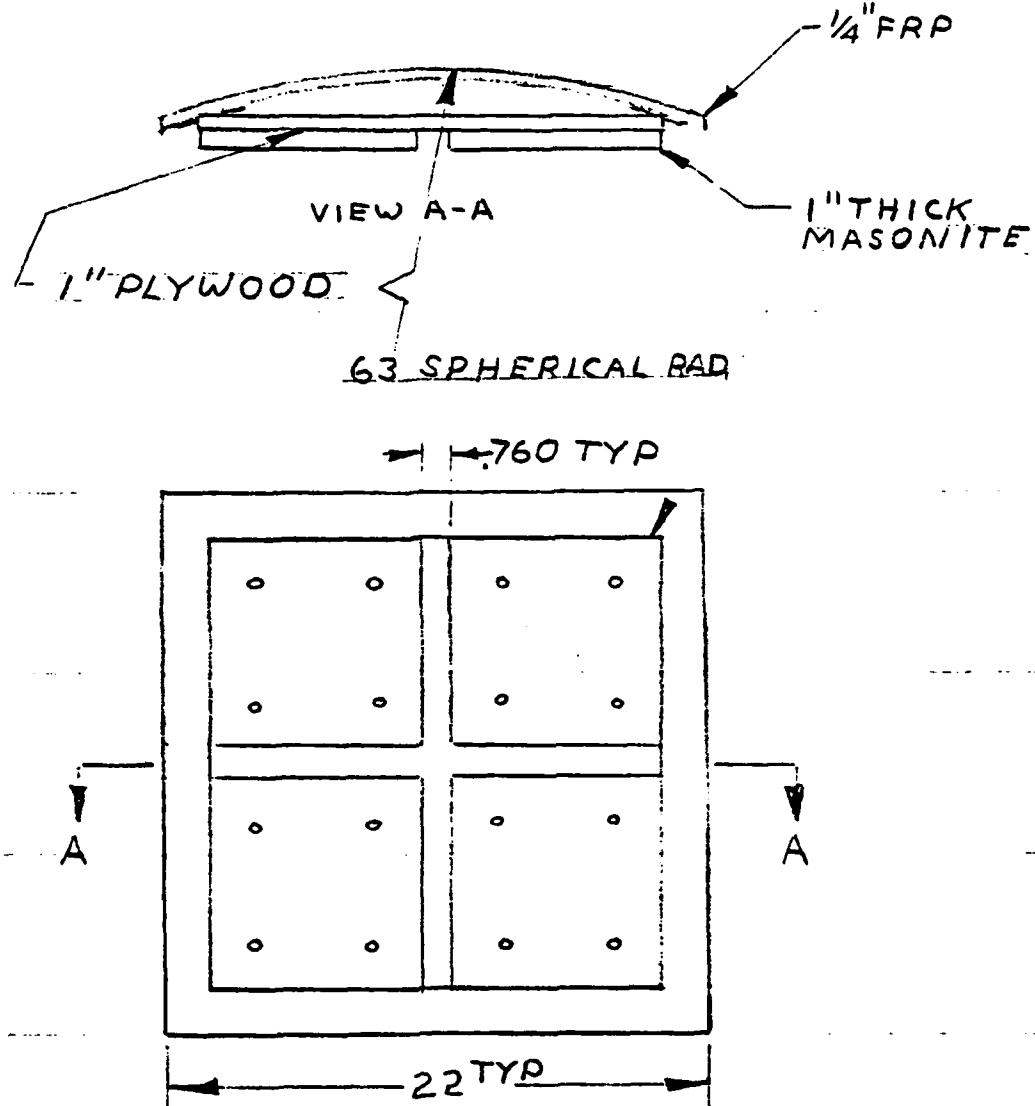
<u>MATERIAL</u>	<u>REQUIREMENTS</u>	<u>STANDARD</u>
POLYPROPYLENE RESIN	PHYSICAL PROPERTIES DIELECTRIC CONSTANT 2.3	ASTM D-2146-69 ASTM D-2520-70
	LOSS FACTOR .0005	ASTM D-2520-70
TUBULAR BLOWN FILM	24 to 27 INCH WIDTH .0044 ± .0004 INCH THICK	ASTM D-374-74 METHOD C STD.
ORIENTED FILM	ORIENTATION RELEASE STRESS 1900 PSI AVG.	ASTM D-1504-70
	TEMPERATURE OF MAXIMUM STRESS 345°F AVG.	ASTM D-1504-70
	THICKNESS .0015 AVG.	ASTM D-374-74 METHOD C
ORIENTED FILM PADS	CROSS PLY FILM PLIES AT 45° ON MANDREL WINDER TO PRODUCE LAYUP AT 1.0 TO 1.25#/FT ² PROTECT WITH 5 MIL POLYETHYLENE AND CUT TO SIZE WITH HOT WIRE	

G. COOK
PREPARED BY
CHECKED BY
DATE: 11/18/79

Swedlow, Inc.

SAW FIXTURE

PAGE NO. OF
REPORT NO.
CUSTOMER NRL



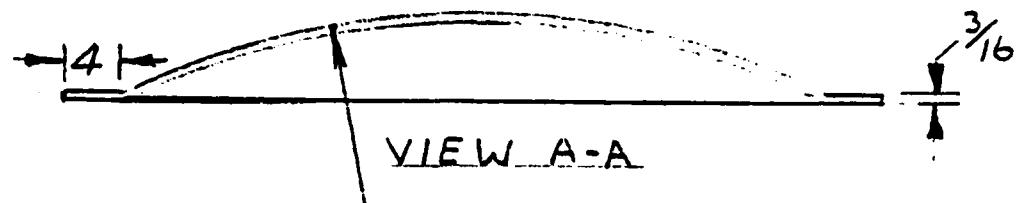
CONSTRUCTION: 1/4 FRP SPHERICAL SKIN
EPOXY BOND & WOOD
SCREW ASSEMBLY AS
REQUIRED

DRAWING 2

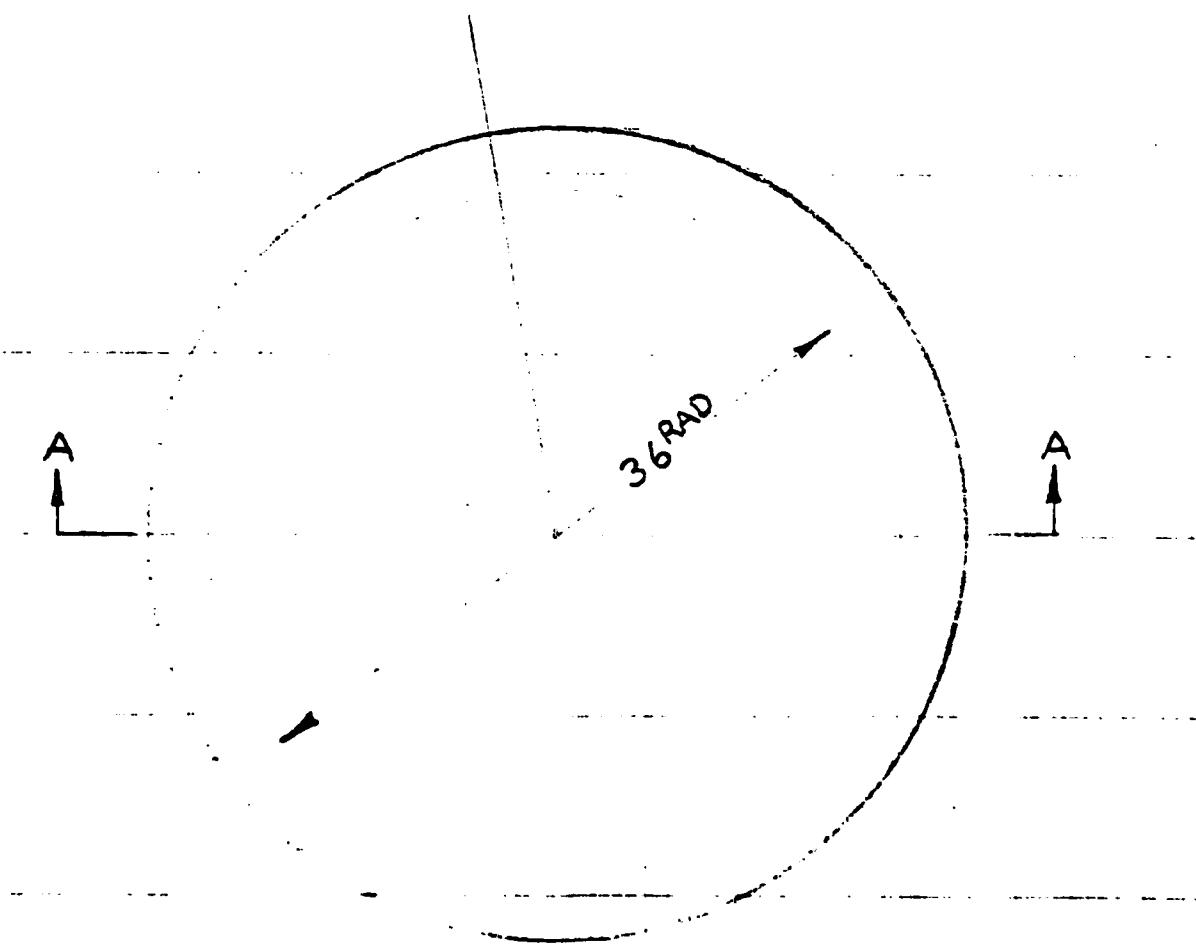
PREPARED BY G.Cook
CHECKED BY *[Signature]*
DATE: 11/17/79

Swedlow, Inc.
FORM FIXTURE

PAGE NO. OF
REPORT NO.
CUSTOMER NRL



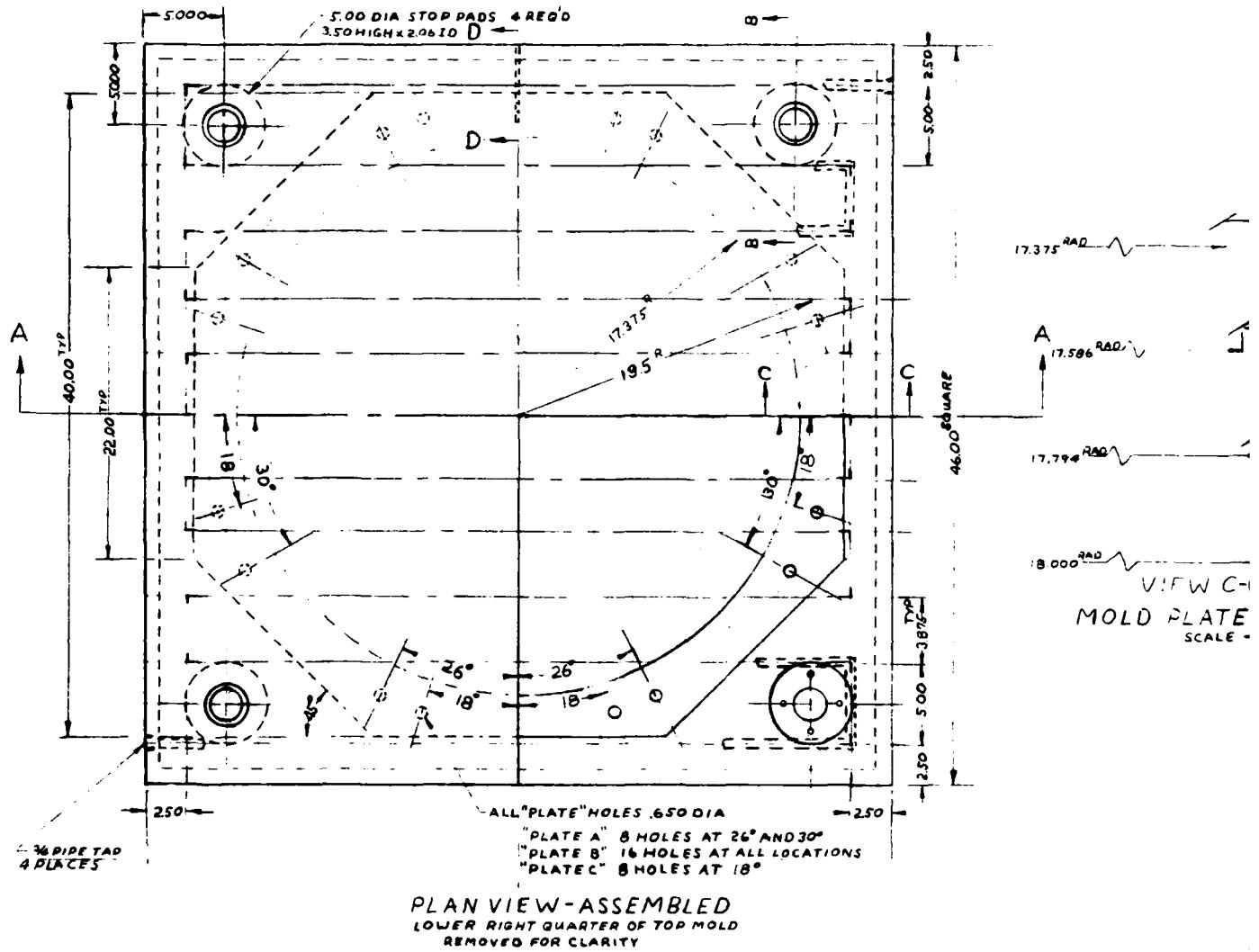
59 RAD. SPHERICAL



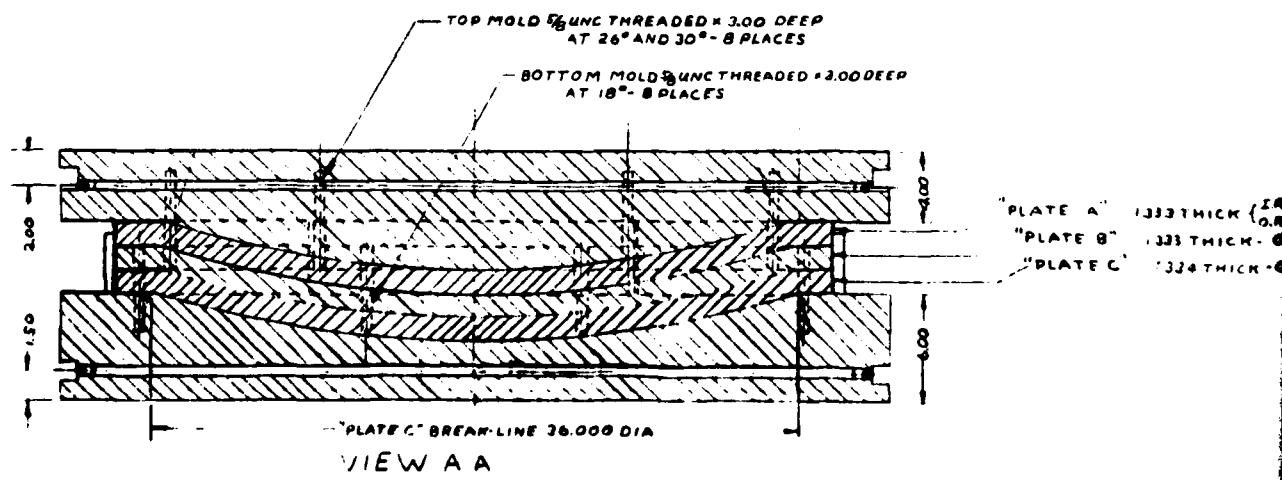
CONSTRUCTION: HIGH TEMP. EPOXY-
GLASS CLOTH

DRAWING I

ALL INFORMATION AND DESIGN DISCLOSED HEREIN WAS ORIGINATED BY AND IS THE PROPERTY OF SWEDELOW INC. SWEDELOW RESERVES ALL PATENT, PROPRIETARY, DESIGN, MANUFACTURING, REPRODUCTION, USE AND SALES RIGHTS THERETO AND TO ANY ARTICLES OR EQUIPMENT DISCLOSED THEREIN EXCEPT TO THE EXTENT RIGHTS ARE EXPRESSLY GRANTED OTHERWISE. THE FOREGOING DOES NOT APPLY TO VENDOR PROPRIETARY PARTS

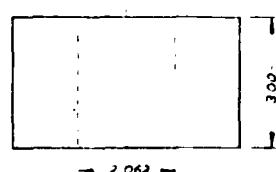
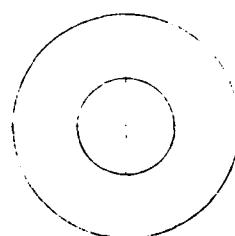
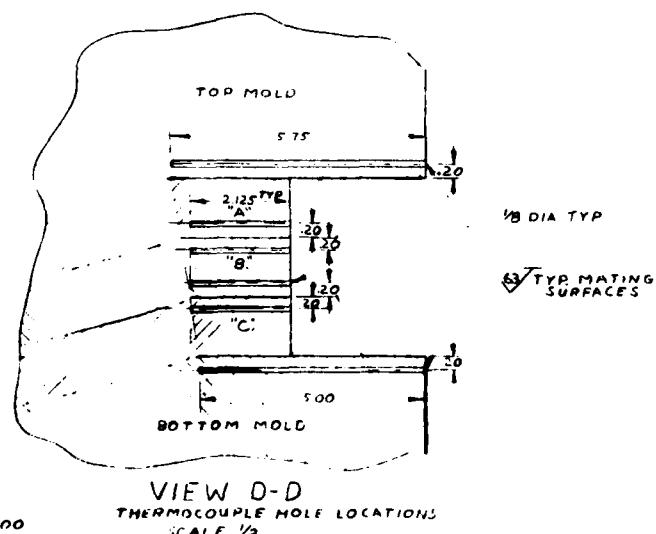
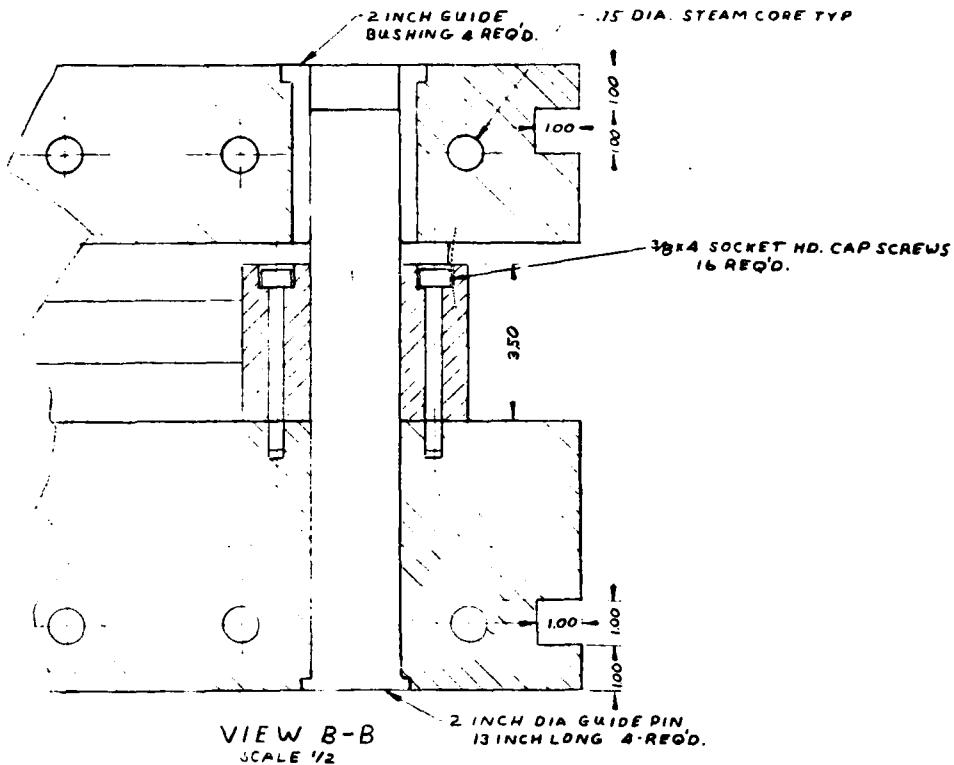
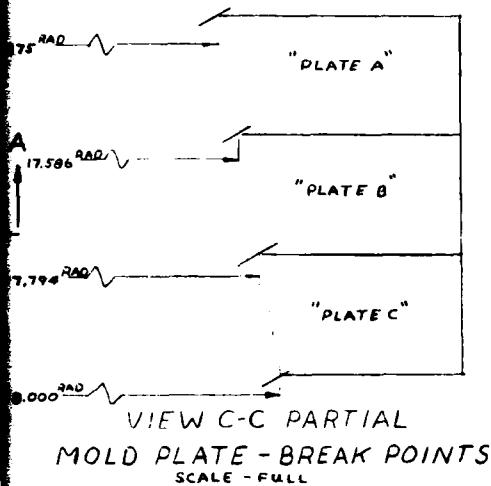


PLAN VIEW-ASSEMBLED
LOWER RIGHT QUARTER OF TOP MOLD
REMOVED FOR CLARITY



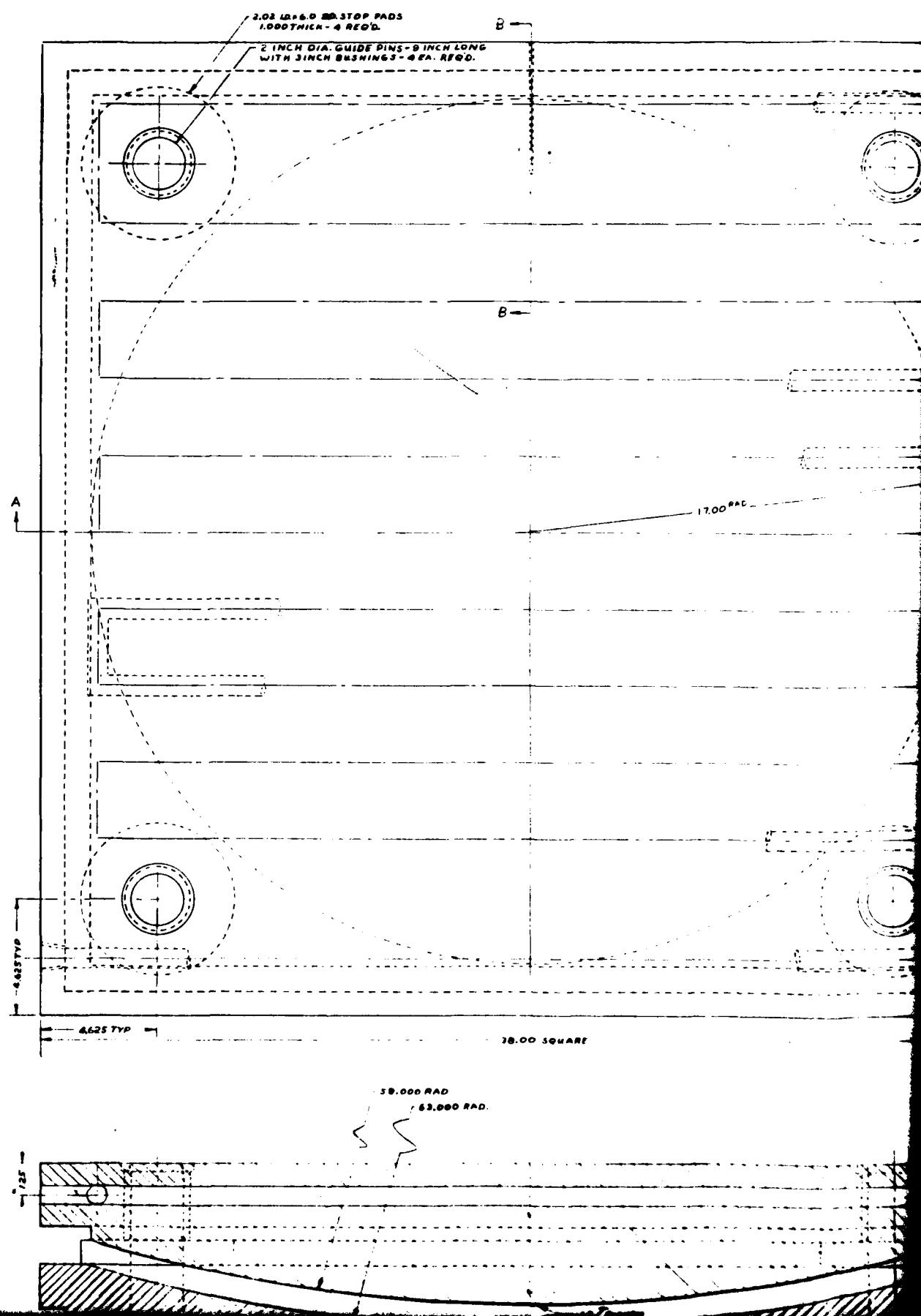
VIEW A A

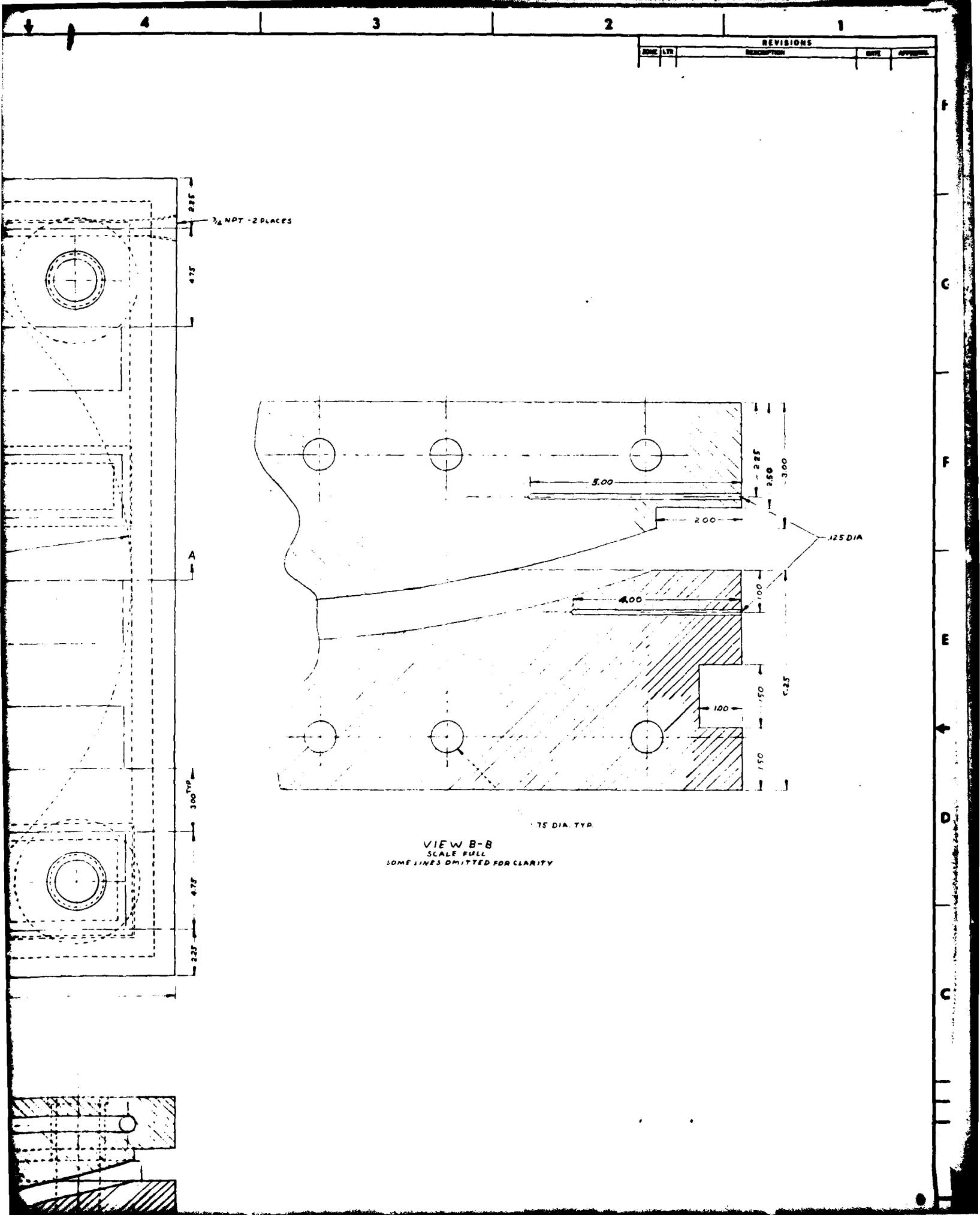
REVISIONS		DATE	APPROVED
ZONE	LIN	DESCRIPTION	

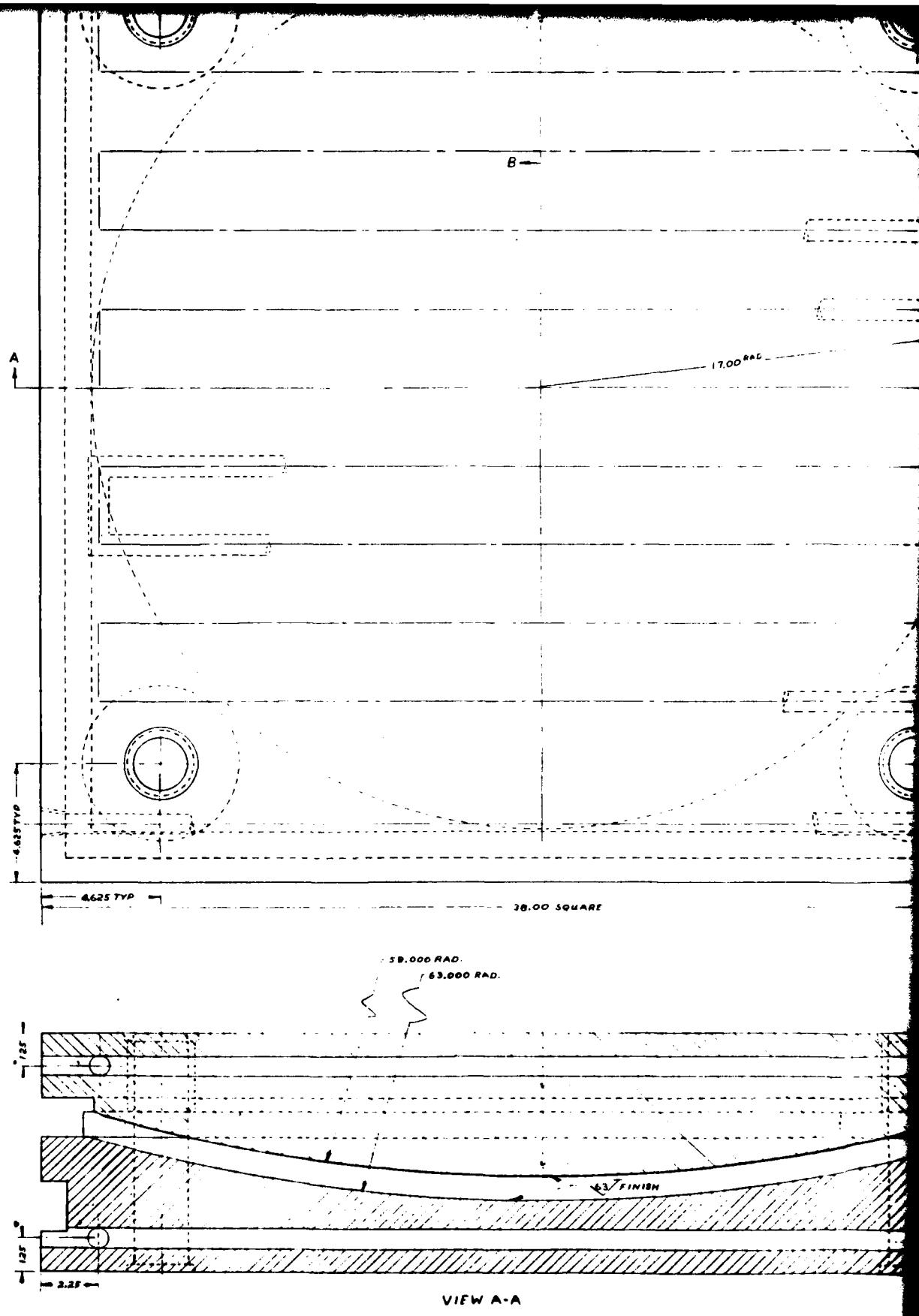


ASSEMBLY PARTS LIST
1/8 UNC SOCKET HEAD CAP SCREWS
16 EA 1-1/2" AND BEA-4"

PRINTED	1/20/01	UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES TOLERANCES ARE FRACTIONS 1/16 DECIMALS .001 ANGLES 10'00	DRAWN BY G.COOK 10/17/01 CHECKED BY J.J.K. 10/17/01	SWEDLOW, INC 12122 WESTERN AVENUE GARDEN GROVE CA 92648
PRINT AND DATE		SPHERICAL DIE ASSY X-P ARMOR		
PRINTED	1/20/01			CODE INVENT NO D 88175 73213







8 7 6 5 4 3

3

